Project Title: Characterisation of Erosion Resistance of 3D Printed Polymers Used in Harsh and Corrosive Environment.

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Industry Challenge:

Polymers and polymer composites are gaining more acceptance in mechanical components industry due to the numerous advantages they possess over the traditional metallic materials. The rising cost of maintenance and repair of existing infrastructural systems is driving the push for a more reliable and cost-effective materials in the mining industry. Although these non-metallic materials have been used in various engineering applications such as in pipes, pipelines, and tanks, the long-term resistance against erosion remains extremely challenging for most engineering polymers today. Design for this type of applications can be further complicated when the mechanical equipment in question will be used to process corrosive and harsh chemical fluids like phosphoric slurries or sand solutions. The objective of this research work is to develop a novel design process in producing a corrosive –resistant polymer and polymer composite structure for processing corrosive fluids such as phosphoric acid solution. This objective would be achieved through development a techno-economic solution for replacing metallic propeller used in axial-flow pump with a lightweight propeller. Understanding the behaviour of polymer and polymer composites in different working environments have been the focal point of research in the last two decades. Many researchers have carried out several test on different high performing polymers and have reported that, polymers have good corrosion resistance, high strength-to-weight ratio, adequate mechanical properties and have ease of handling. All these advantages have given polymers an advantage over some metals and metal alloys, and polymers have generally been proposed for a wide varieties of engineering applications including, building construction, oil and gas tanks and pipelines, aircraft, and marine applications. But, despite all these advantages, erosion resistance of industrial polymers are yet to be understood, especially the 3D printed polymers. The research work presented here forms part of the work packages carried out as part of my industrial PhD research program which started in November 2000 and will be rounding off by October 2024. The erosion behaviour of some selected polymers and polymer composites was examined with solid particle impingement using water jets erosion test rig (Figure 1). Erosion tests were conducted for varying impinging angles of 90^o, 60^o, 45^o, 30^o, and 15^o angles at a jet velocity of 23m/s at an average temperature of 45^{o}C. A 400µm angular Silica oxide sand was used as the erosion particle.

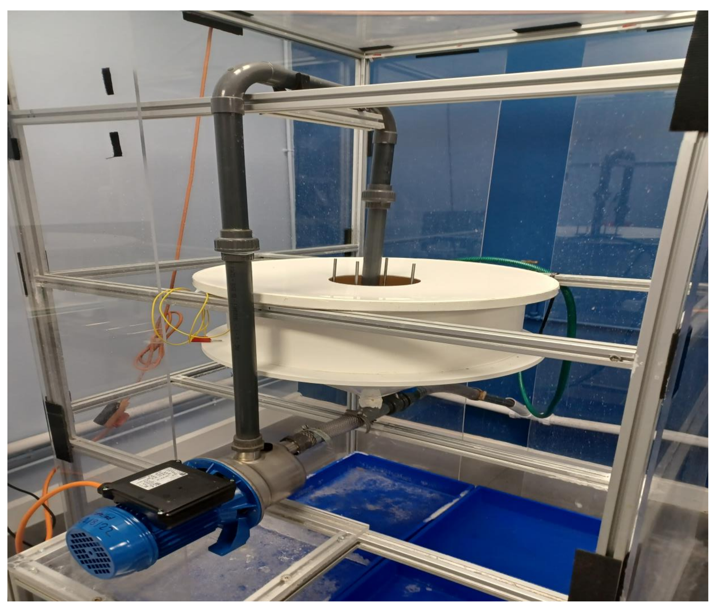

Figure 1 – Erosion Test Rig

Figure 2 – Sample Grinding Machine

Figure 3 – Sample Holders

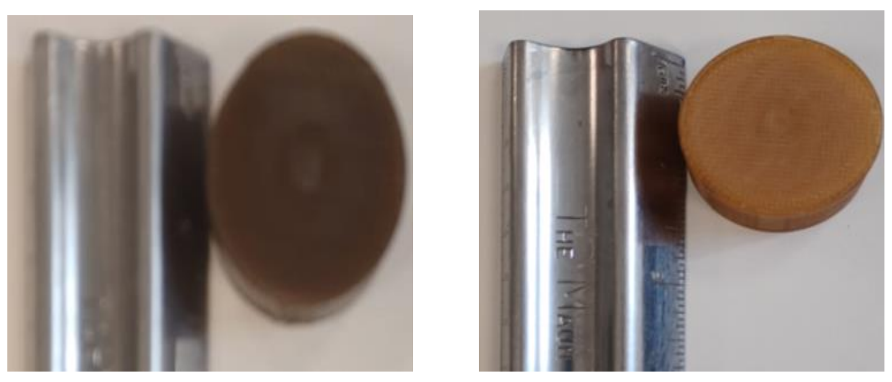

Figure 4 – Erosion samples after impingement

Figure 5 – Silica Oxide Sand

Proposed Research:

The proposed research centres on investigating the resistance of 3D printed polymers in harsh and corrosive environments. The scope of this research is set out to cover the knowledge gap in polymers corrosion resistance, structural integrity under hot chemicals pumping, erosion resistance, manufacturability, and design for manufacture, and lots more. It is validating ongoing computational work but more importantly also fundamentally understand the design principle and methodology for implementing lightweight composites and additively manufacturing products for harsh duties. Erosion laboratory test presented in this poster is a section of the overall PhD research work carried out at the University of Strathclyde and supported by industrial sponsor who is a manufacturer of rotating machineries (Pumps) . These products, while designed to optimize the running equipment, are limited in their efficiency due to the weight of the heavy and overhanging propellers. To further increase efficiency, and to reduce the duty of running equipment required (bearings, mechanical seals, shaft size, etc.), there is a need to reduce the propeller weight. One possibility is to use a polymer material rather than metal which is currently in use. These pumps are used in phosphoric acid service with minimum amounts of dissolved, aqueous gypsum. The pump's components in contact with the service fluid must be made of a chemically resistant material that also delivers the mechanical strength required to resist large, infrequent rocks that float through the process fluid. Recent progress made through a similar project has showed promising results for enabling light weighting opportunities for rotating machineries. The adoption of composites and their manufacturing methods for these products will lead to unique opportunities in the markets for the business sponsor. However, the composite materials robustness in the environments that these products are applied has not been fully evaluated and has focused on computational modelling and finite element analysis and no practical work has been carried out to verify several crucial areas such as erosion resistance, structural integrity under hot chemicals pumping, chemical resistant coating, manufacturability, and design for manufacture. Successful delivery of this project will provide the business with an alternative solution to address the total cost of ownership challenges being set by their customers and demonstrate technological leadership from the impacted Weir products. Not undertaking this study leaves Weir brands iterating their current solutions for incremental improvements and continuing to battle to maintain their market position against low cost/technology competitors. One important aspect still missing for both AM and moulded polymer composites is the understanding of the resistance to erosion effect on their performance retention rate (propeller lifetime). These gaps have been addressed in this research work. My PhD work has addressed some fundamental research questions aimed at providing basic design information to the designer who are task with designing such polymer structures. Hence, this work undertaken under the lightweight propeller project is set out to cover all the identified gaps (erosion & corrosion resistance, hydraulic characteristics, and structural integrity). Some of the major gaps this research will address include.

- Missing full AM material data and temperature dependence of polymers and polymer composites.
- Unclear about thermo-chemical resistance of polymers under static and dynamic stresses.
- Unclear about performance retention rate of polymeric structures.
- **Unclear about Erosion resistance of polymeric structures.**
- Evaluation of the fatigue and creep response of polymers and polymer composites.
- Building of a laboratory scale of lightweight propeller test rig to validate polymer materials of different grades and types.

Two 3D printed high performing pure polymers were selected by the industrial partners to be tested in a laboratory environment, these includes; a) Antero 800 NA – This is a PolyEtherKetoneKetone (PEKK) based thermoplastic with excellent mechanical properties and excellent resistant to most industrial chemicals. They are manufactured by Additive Manufacturing (AM) method known as Fused Deposited Modelling (FDM). b) Ultem 1010 – This are high performing Polyetherimide (PEI) thermoplastic with high heat resistant and excellent mechanical properties. They are manufactured by Additive Manufacturing method known as FDM. The sample specimens used for this laboratory were printed in two different printing orientations, namely XY printing orientation otherwise known as Upright, and ZX orientation otherwise known Onedge orientation.

Desired Outcomes / Impacts:

The outcome of the erosion resistance laboratory experiment presented results that shows the mass loss versus the impingement angles of the polymers, it provides the information about the impact of printing orientations on the mass loss results, and also gives information about the depth of the scars observed on the surface of the test specimens. The graph below presents the results of the experiment and information of the erosion performance of the 3D printed polymers.

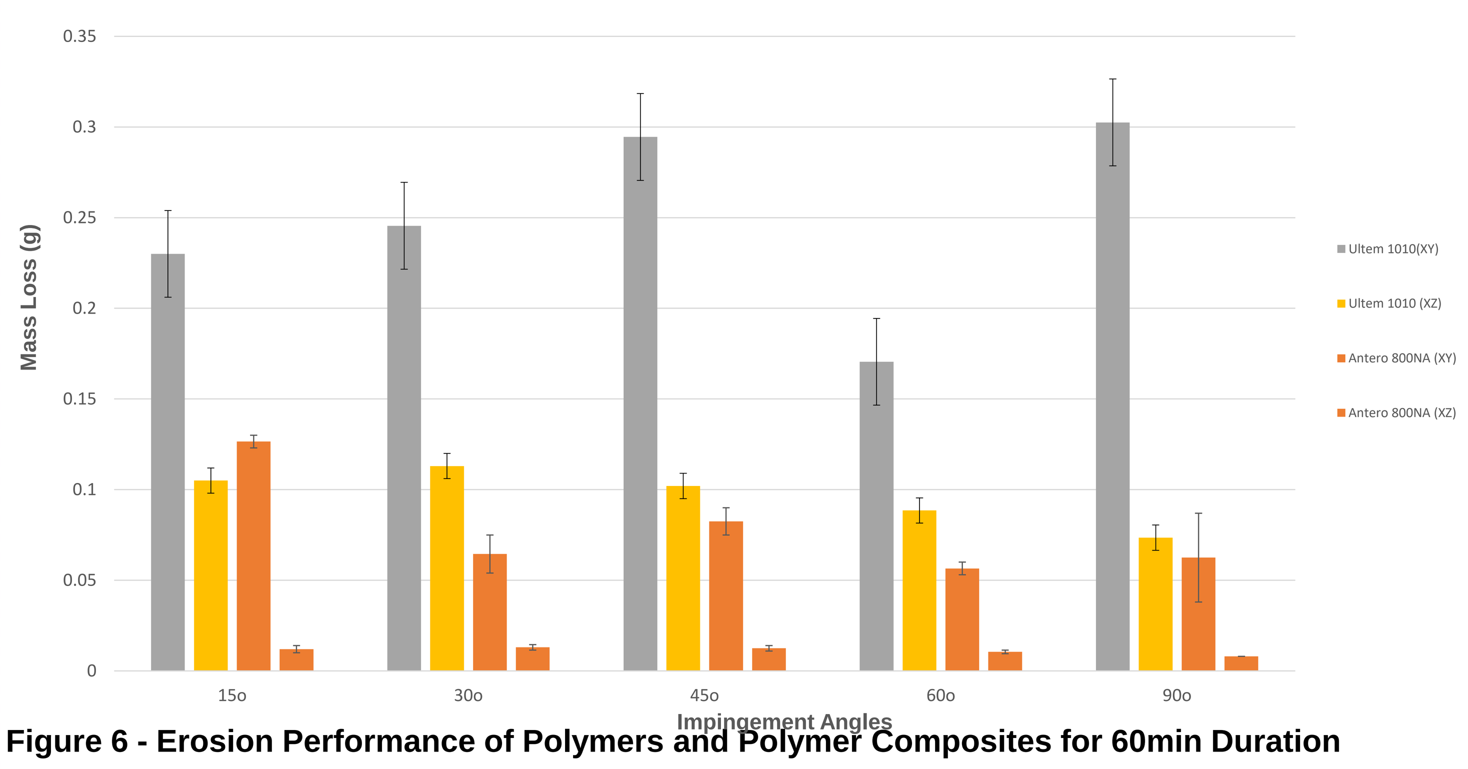

Figure 6 - Erosion Performance of Polymers and Polymer Composites for 60min Duration

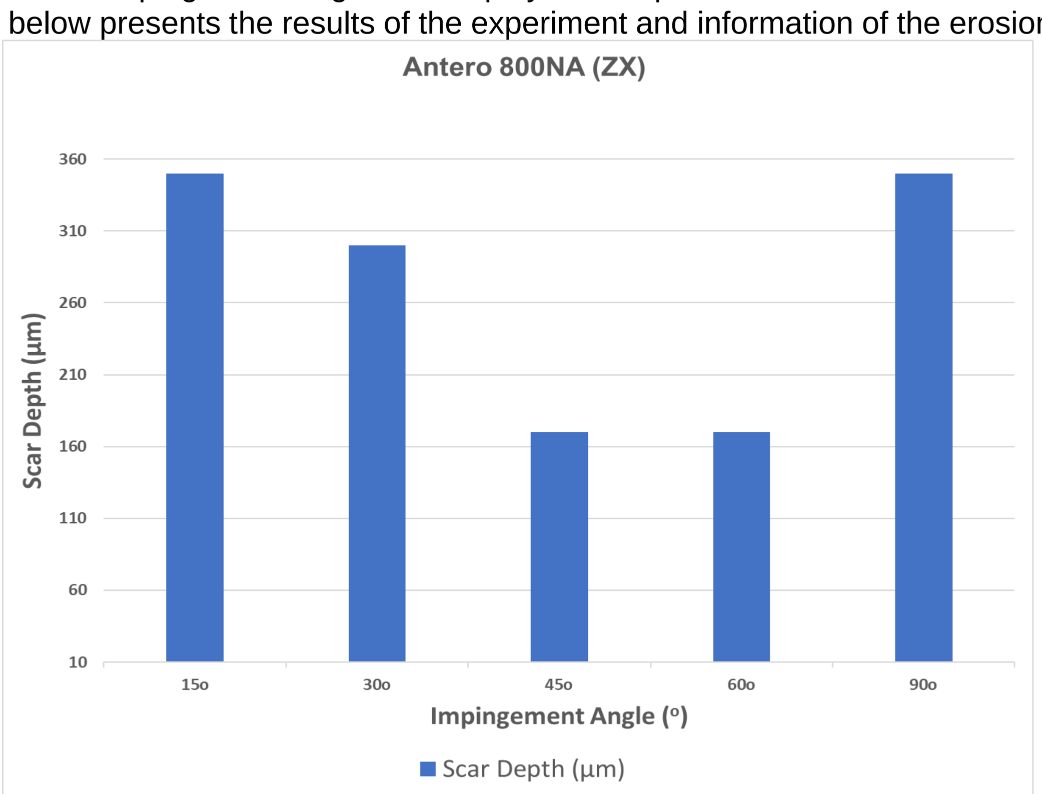

Figure 7 – Erosion Scar Depth of 3D Printed PEKK Polymer

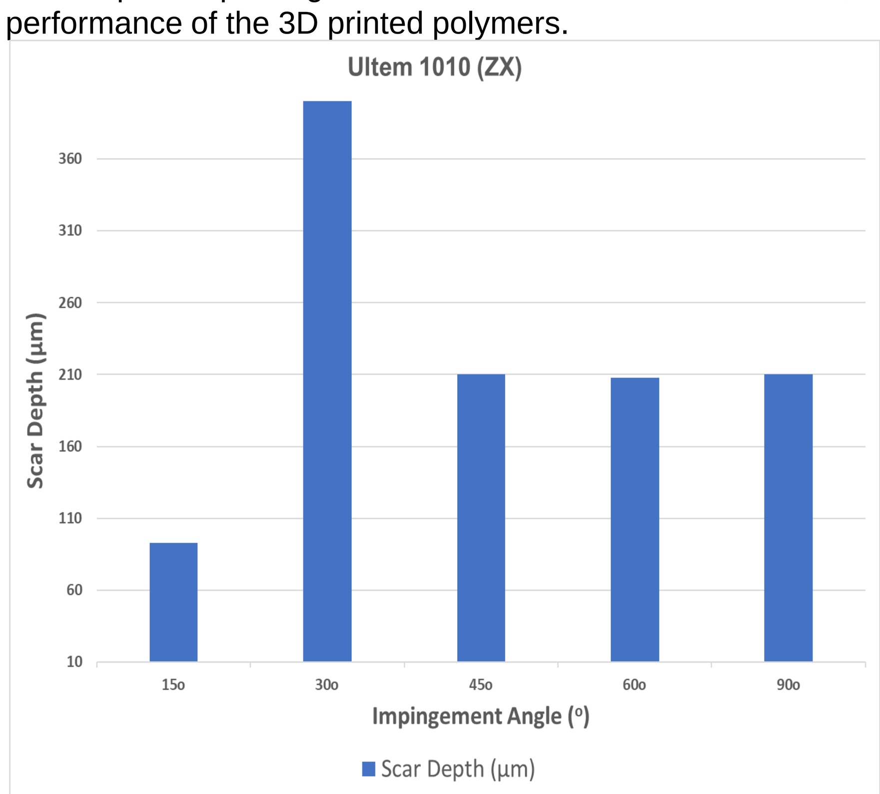

Figure 8 – Erosion Scar Depth of 3D Printed PEI Polymer

Scottish Research Partnership in Engineering
NMIS National Manufacturing Institute Scotland
WEIR Advanced Research Centre
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